The Enlist™ Weed Control System and Weed Resistance Management

Author(s): David Simpson

Executive Summary:

Herbicide resistance has been steadily increasing since the 1980s. Herbicide selection pressure, as the result of repeated use of a single herbicide mode of action, is the primary explanation for evolution of herbicide resistance, particularly for single site of action herbicides. In the 1980s, acetolactate synthase (ALS) inhibiting herbicides were commercialized and became the predominant mode of action for weed control in corn, soybean and cereal crops, creating high selection pressure, and by the late 1980s ALS resistant populations were confirmed across wide geography. In the mid-1990s, glyphosate tolerant cotton and soybean were introduced, and by the year 2000 over 50% of the cotton and soybean acres in the US were receiving multiple applications of glyphosate within a season and year after year (Benbrook 2016). While resistance to glyphosate was once considered highly unlikely, the extraordinary selection pressure created by glyphosate use resulted in the first cases of resistance in the early 2000s (Bradshaw et al 1997). Repeated use of 4-Hydroxyphenylpyruvate dioxygenase (HPPD) inhibiting herbicides in corn seed production fields, where seed corn is grown year after year, has resulted in selection of HPPD resistant waterhemp (*Amaranthus rudis*). Overreliance on protoporphrinogen oxidase inhibiting (PPO) herbicides for control of glyphosate resistant waterhemp and Palmer amaranth (*Amaranthus palmeri*) contributed to the selection of PPO resistant populations of those weeds. Recently, the University of Arkansas confirmed a Palmer Amaranth population resistant to glufosinate after 10 years of continuous glufosinate use.

First introduced in 1945, 2,4-D (2,4-dichlorphenoxyacetic acid) herbicide has been used for over 75 years in the US. 2,4-D is an auxinic herbicide that mimics indole acetic acid (IAA) resulting in disruptions in hormone balance, uncontrolled and disorganized plant growth that leads to plant death. While scientists have measured physiological responses caused by 2,4-D, the complex mode of action for auxinic herbicides has not been fully elucidated even after seven decades of research (Peterson et al 2016). After 75 years of use in the US, six weed species with resistance to 2,4-D have been reported in the US (Heap 2021). The relatively low incidence of resistance to auxinic herbicides has been attributed to the presence of rare alleles imparting resistance in natural weed populations, the potential for fitness penalties due to mutations conferring resistance in weeds, and the complex mode of action of auxinic herbicides in sensitive dicot plants (Mithila et al. 2011).

Stewardship of new herbicide technologies with herbicide resistance management program is critical for their long-term utility (EPA Pesticide Registration Notice 2017). Industry, academia, regulatory agencies and grower associations agree on the need to implement diversified weed management strategies that includes cultural, mechanical, herbicides and sanitation practices to manage herbicide resistance. Educational programs are needed to help growers implement diversified weed management strategy, understand the importance of managing weed seed banks, and how to detect early signs of resistance.

The Enlist™ weed control system is structured around 2,4-D, glyphosate and glufosinate tolerant soybean, corn and cotton varieties and one of the specially designed 2,4-D-containing herbicides, Enlist One® or Enlist Duo®. The Enlist weed control system promotes a program approach utilizing the best management practices for managing herbicide resistance as defined by the Weed Science Society of America (Corteva 2021, Norsworthy 2014). The Enlist weed control system recommends starting with a clean seed bed through tillage or burndown herbicide applications, use of residual herbicides at

planting, timely post-emergence application of 2,4-D choline plus glyphosate or glufosinate to small weeds, inclusion of additional residual herbicide at the post-emergence timing, scouting following application, and second post-emergence applications if needed to achieve control of new germinated weeds. A key advantage of the Enlist™ weed control system is that Enlist crops (E3 soybeans and cotton) provide tolerance not only to 2,4-D, but also to glyphosate and glufosinate which allows three different herbicide modes of action to be utilized in the postemergence application. Enlist One® herbicide should always be applied to Enlist E3® soybeans and cotton with either glyphosate or glufosinate so a minimum of two modes of action are being applied to minimize the potential for selection of resistance.

During the past four years since introduction of the Enlist weed control system, Enlist herbicides have been applied to more than 26 million acres of Enlist cotton, corn and Enlist E3 soybean. From 2017 to 2020, Dow AgroSciences and Corteva trained 43,000 retailers, seed sellers, farmers and applicators on how to use Enlist weed control system to maximize control and ensure on-target applications. Since introduction of the Enlist weed control system, there have been no confirmed reports of lack of weed control from likely resistance. Waterhemp and Palmer amaranth pose the highest risk of developing resistance in evidence by the prevalence their resistance to glyphosate and other herbicides. For glyphosate resistant weeds, the best Enlist herbicide recommendation (for E3 soybeans and cotton) is 2,4-D plus glufosinate or a three-way mixture of 2,4-D plus glyphosate plus glufosinate to ensure two effective modes of action are in the post-emergence application. In the latest revision of Enlist One herbicide label submitted to EPA, Corteva has removed low use rates of 2,4-D in favor of a single high rate to ensure growers are using full use rates on glyphosate resistant weed.

Corteva and the US EPA Pesticide Registration Division have a mutual interest in maintaining the long-term utility of weed management tools, including the Enlist weed control system. Enlist crops allow Enlist herbicides (containing 2,4-D choline) to be used over the top of soybean and cotton, bringing an additional effective mode of action to combat herbicide resistance. The ability to tank mix Enlist One with glufosinate reduces the selection pressure for 2,4-D and glufosinate resistance, thus increasing the longevity of both 2,4-D and glufosinate. Furthermore, the Enlist system reduces the selection pressure for protoporphyrinogen oxidase (PPO) inhibiting herbicides, thus extending the utility of PPO herbicides as another effective mode of action in cotton and soybean. Corteva has invested in an industry leading stewardship program with focus on the whole system to ensure growers are implementing the best practices for resistance management and monitoring for early detection of weed resistance. Grower adoption of integrated weed management will be key to successful management of herbicide resistance rather than more regulations on herbicides. Corteva is committed to the Enlist weed control system and working with growers to ensure the long-term viability of the Enlist weed control system.

The Enlist™ Weed Control System and Weed Resistance Management

Evolution Weed Resistance to Control Methods

Failure to control weeds can reduce yields by 52% in corn and 49.5% in soybean in the US. (Weed Science Society of America 2017). Growers use cultural, mechanical and/or chemical methods to control weeds to prevent yield loss. All weed control methods create a set of conditions that select for weed species or individuals within a given species that have an advantage for survival and reproduction resulting in the propagation of species or individuals. For example, changing from conventional tillage to no-till soybean production in the US increases the presence of winter annual weeds including horseweed, perennial weeds and summer annual grasses, and decreases the presence of large-seeded broadleaf weeds. Weeds adapted to mowing tend to grow short, in a rosette form or creeping above the soil surface. Herbicide use may result in a shift from weed species controlled by the herbicide to weed species that is not controlled. For example, following introduction of 2,4-D in the 1940s and ability to control broadleaf weeds, there was a shift in focus from broadleaf to grass weeds.

Herbicide use can result in the selection of individuals within a population that can survive the herbicide application that controls the rest of the population. These individual survivors or biotype are referred to as resistant to the herbicide used. If these individual survivors can grow, flower, and produce seed, then in the following year the number of survivors will increase in the field if the same herbicide is used. After several seasons of selection, herbicide resistant weed biotype will come to dominate the population in the given field. The level of selection pressure is determined by several factors including; number of applications per year, length of residual herbicide activity, efficacy level, the number of effective herbicide modes of action used and how often the herbicide mode of action is used in the crop rotation.

These individual survivors have a genetic difference that results in a physiological resistance mechanism that allows them to survive. Genes that enable weed species to resist herbicides are present in all weed populations but at low frequency (Herbicide Resistance Action Committee 2021). Herbicides do not cause the genetic difference that lead to herbicide resistance, rather their repeated use over time selects for the genetic differences that result in resistance.

Herbicide Resistance Mechanisms

The mechanisms that convey herbicide resistance can be classified as target site and non-target-site (Delye et al. 2013). Target site resistance involves a mutation or amplification in the protein that the herbicide inhibits. The classic target site resistance is a single point mutation in the underlying DNA that changes an amino acid in the protein binding site which reduces or prevents the binding of the herbicide resulting in the reduced susceptibility to the herbicide. Gene amplification, first discovered in glyphosate resistance, is an increase in the number of copies of a gene resulting in over production of the target protein present to a point that the concentration of herbicide is insufficient to inhibit enzyme activity at levels leading to plant death. Non-target-site resistance involves mechanisms that prevents sufficient concentration of herbicide from reaching the target site to provide control. Increased metabolism of the herbicide in the plant is a common non-target site resistance mechanism. Reduced translocation is a mechanism that can impact herbicides that must be in the meristematic tissue to control the plant. Reduced translocation can be due to sequestration in the cell vacuole, trapped in leaf tips or trapped in necrotic tissue.

Herbicide Resistance Mechanisms in 2,4-D Resistant Plants

2,4-D and the other auxinic herbicides have a complex mode of action that even after 75 years is not completely understood (Peterson et al. 2016). Scientists have studied the physiological responses caused by 2,4-D and understand that 2,4-D mimics indole acetic acid (IAA), an auxin. IAA is a critical plant hormone responsible for modulating such diverse processes as tropic responses to light and gravity, general root and shoot architecture, organ patterning, vascular development and growth in tissue culture (Woodward and Bartel 2005). IAA is highly regulated in plants with multiple sites of action; thus it is highly unlikely that resistance will develop due to target site resistance. The potential for resistance to 2,4-D is most likely based on non-target site mechanisms that reduce 2,4-D concentrations in the meristematic tissue (Peterson et. Al 2016).

Globally, there are 25 species that have been confirmed resistant to 2,4-D. Characterization of mechanisms of resistance has been investigated in only a few of these weeds (Mithila et al. 2011). To date, there are no published reports unequivocally describing an insensitive or less-sensitive auxin receptor or auxin binding protein that confers resistance to 2,4-D (Peterson et al 2017). While past research has implicated ABP1 as a binding site for 2,4-D, recent data indicates that ABP1 is not involved in auxin signaling thus raising question if ABP1 is involved in 2,4-D resistance (Peterson et. al 2017). Research on 2,4-D resistant corn poppy populations have shown reduced translocation and increased metabolism but studies have not fully elucidated if there are two separate mechanisms or if reduced translocation is due to increased metabolism (Peterson et al 2017). In review of six 2,4-D resistant dicot weeds, Bautista found enhanced metabolism and reduced translocation as the primary mechanisms for the resistance. (Palma-Bautista 2020)

In the US, there are 6 species with confirmed resistance to 2,4-D (Heap 2021). Of interest is 2,4-D resistance in waterhemp and Palmer amaranth. A 2,4-D resistant waterhemp population found in grass seed production field in Nebraska was found to have increased metabolism of 2,4-D, likely mediated by cytochrome P450 (https://pubmed.ncbi.nlm.nih.gov/29194949/). A multiple resistant waterhemp population (ALS, PPO, HPPD, atrazine, EPSPS and 2,4-D) from Missouri exhibited increased metabolism of 2,4-D. Research on the multiple resistant Palmer amaranth population from the Kansas Conservation Tillage Project site indicates that resistance to 2,4-D is likely due to a P450 mediated metabolism mechanism (Figueiredo et al. 2018). Based on current knowledge of resistance, expectations are that non-target resistance mechanisms, particularly metabolism, will remain the most likely resistance mechanisms for 2,4-D. P450 mediated metabolism is not limited to 2,4-D but has also been shown to confer resistance to atrazine, HPPD, long chain fatty acid and dicamba herbicides. Of concern is that selection for metabolic resistance by one herbicide can result in resistance to other herbicides even herbicides not currently discovered.

Problematic Resistant Weeds in US Cotton, Corn and Soybean Acres

Waterhemp and Palmer Amaranth have been ranked as the most troublesome weeds in soybean and cotton, respectively (WSSA 2017). Both species are dioecious plants (separate male and female plants) thus there is a mix of genes when the plant reproduces resulting in greater genetic diversity than most other agronomic monoecious weeds. Both are prolific seed producers with waterhemp plants capable of producing over 250,000 and Palmer amaranth capable of producing 600,000 seeds per plant. Even with low frequency of resistance, high seed production with high genetic diversity increases potential for resistance. Waterhemp and Palmer amaranth have developed resistance to inhibitors of ALS, PPO, HPPD, photosystem II (PSII), Very Long-chain Fatty Acid synthesis and EPSPS (Heap 2021). More troublesome is that both species have populations that are resistant to two to seven different herbicide modes of action (Heap 2021). In isolated cases, resistance to auxin herbicides has been reported. Target site resistance is primary mechanism for ALS and PPO herbicide resistance. Amplification of gene number is primary mechanism for EPSPS resistance. Metabolic resistance is the primary mechanism for HPPD, PSII and very long-chain fatty acid synthesis herbicide resistance. In the limited instances of auxin resistance, metabolic resistance is considered the likely resistance mechanism with potential for the same P450 enzymes to be metabolizing HPPD and PSII herbicides as well as 2,4-D.

The current limited instances of 2,4-D resistance in waterhemp and Palmer amaranth are not associated with the commercial use of Enlist™ herbicides. The 2,4-D resistant waterhemp found in 2009 was in a grass seed production field where 2,4-D had been used for numerous consecutive years and resistance was limited to the farm. The waterhemp identified in 2016 in Illinois with reported resistance to 2,4-D was initially investigated due to a failure to control with HPPD herbicides and was screened for resistance to ALS, atrazine, PPO and 2,4-D. There was no field history of 2,4-D use in recent memory thus indicating that 2,4-D resistance was likely selected for by HPPD herbicide use (personal communications with Dr. Aaron Hager 2017). In Kansas, two Palmer amaranth populations have been identified as 2,4-D resistant. The first population collected in 2016 during a random road survey and characterized in the greenhouse by Dr. Vipan Kumar at Kansas State University. In 2020, field trials on the field where the sample was collected from showed low populations of Palmer Amaranth and without resistance, likely due to diversified weed management program implemented between 2016 and 2020 (personal communications with Dr Kumar 2020). In the second Kansas location, the resistance was detected in a field area being used for a long-term conservation tillage trial with 45 plus years of continuous sorghum where 2,4-D was routinely used.

Horseweed (*Conyza canadensis*) presence in soybean and cotton fields increased after the adoption of glyphosate tolerant crops due to an increase in reduced or no tillage systems which favors winter annuals. ALS and glyphosate resistance are prevalent and has allowed horseweed to expand across the Midwest since the 1990's. ALS resistance is due to a target site mutation and glyphosate resistance is due to sequestration mechanism. Auxin herbicides remain effective on horseweed though some greenhouse data has shown some variation in dose response curves but no cases of auxin resistance (Kruger et. al 2010).

Giant ragweed (*Ambrosia trifida*) can be a problem in some areas with ALS and glyphosate resistance being reported. ALS resistance is due to an altered target site. The mechanism for glyphosate resistance is currently unknown but it is likely not target site resistance that results in rapid necrosis within hours of application limiting the translocation of glyphosate to the meristematic tissue and axillary buds. Regrowth occurs from these meristematic tissues after the necrotic leaves fall off. 2,4-D remains active on giant ragweed though the rapid necrosis from glyphosate application could potentially reduce 2,4-D translocation when 2,4-D is applied with glyphosate.

Spread of Herbicide Resistance

The presence of herbicide resistant weed in a field may have resulted from two sources. The first is the independent selection of a resistant biotype from the weed community already present in the field. The second involves the introduction of resistant trait from a field with an existing resistance problem to fields without resistance by either pollen or seed movement (Hartzler 2011). Independent selection is dependent on the selection pressure previously discussed. Evolution of glyphosate resistant Palmer amaranth and waterhemp has highlighted the numerous ways that weed seed can be spread from field to field. While these methods have been known for decades, they often are forgotten until there is a problem.

Pollen mediated movement of resistant trait from a single field to other fields is a primary concern for dioecious weeds such as waterhemp and Palmer amaranth. University of Georgia field study quantified as much as 20 to 40% outcrossing among Palmer amaranth plants within 1000 feet apart (Sosnoskie et al. 2017). Researchers at University of Illinois predicted that waterhemp pollen could move approximately 3 miles by wind (Liu et al. 2010). While pollen dispersal by wind can result in fairly long distance movement, there are a number of factors that influence pollen mediate movement of resistant trait such as viability of the pollen and presence of receptive plants to intercept the pollen. Pollen movement from one field to adjacent fields is a concern for dioecious plants but of limited concern for monoecious plants. Pollen movement within a field increases the speed at which a single resistant plant can spread the resistant trait within a field and shift the frequency of resistance within a population.

Glyphosate resistance was shown to move by equipment, animal feed and seed. Within a farming operation, movement of equipment from field to field, particularly combines, is a primary mechanism resistance is spread from a single field to multiple fields. Palmer amaranth seed, a problem weed typically found in the south, moved into dairy production areas of Ohio, Indiana and Michigan as contamination in cotton seed, hulls and meal used in feed rations. Seed sold for plantings in Conservation Research Enhancement Program (CREP) have been contaminated with Palmer amaranth seed and appears responsible for the spread of glyphosate resistant Palmer amaranth in Illinois, Iowa and Ohio (Loux 2013). Purchases of equipment from areas where glyphosate resistant Palmer amaranth is present has been identified as source for introduction into new areas. Movement of Palmer amaranth seed from the bootheel of Missouri via shared combines for horseradish was identified as likely introduction route in southern Illinois (personal communications Dr. Bryan Young 2014). Wildlife such as ducks has been associated with movement of resistant Palmer amaranth from field to field (Farmer et al. 2017). Weeds growing along field edges, ditches and roadsides can be a source of introduction of resistance into a field. Growers need to manage the weeds on field edge to prevent propagation and movement into the field (Bagavathiannan et al.)

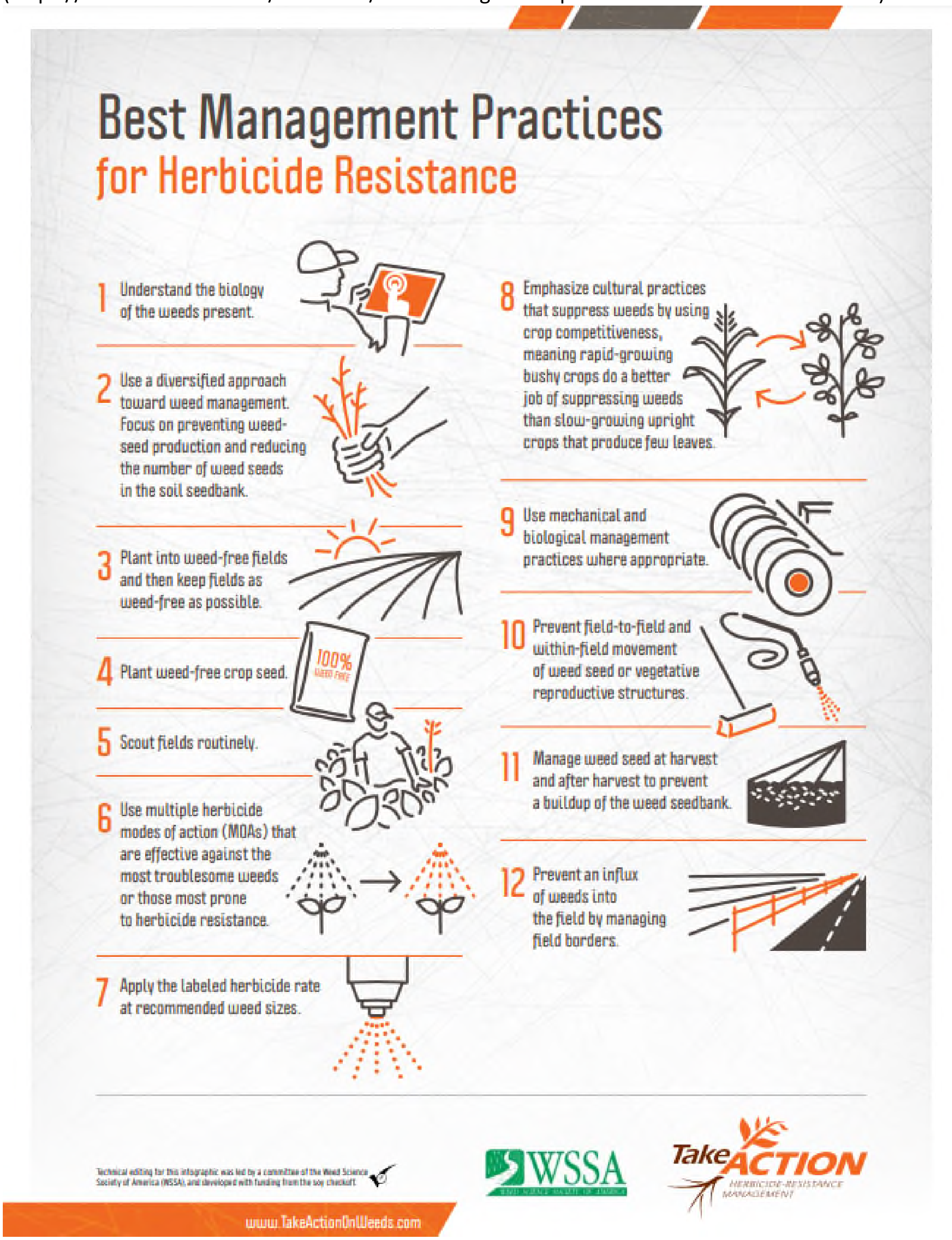
Reducing the potential of resistance spreading via movement by man is a key component to minimize spread of resistance. Best management practices for managing herbicide resistance must also include reducing movement from field to field through cleaning of equipment.

Best Management Practices for Herbicide Resistance Management

Resistance to glyphosate in the US has received unprecedented attention outside the weed science community, resulting in awareness of herbicide resistance among farmers, consultants, retailers, weed scientists, industry representatives and some government agencies. Educational programs such as Take Action are funded by commodity groups and ag chemical companies to help farmers manage herbicide resistance with the goal of encouraging farmers to adopt management practices that lessen the impacts of resistant weeds and preserve current and future crop protection options (“TakeAction Pesticide Resistance Management”, 2021). Research on herbicide resistance has enhanced our understanding of resistance development and frequency of resistance in the natural population. Resistance modeling utilizing this new information shows that use of multiple effective modes of action within a season is more effective than the previous recommendations calling for annually rotating herbicide mode of action.

Over the past decade, more emphasis has been placed on implementing a diversified weed management plan rather than total reliance on herbicide use. Increased emphasis is being placed on reducing the amount of seed produced and allowed to return to the soil seed bank. Weed Science Society of America has defined 12 best management practices for herbicide resistance; understanding weed biology, diversified weed management with focus on reducing weed seed, start with a weed free field, plant weed free crop seed, use multiple effective modes of action (MOAs), scout timely applications with full labeled rate, maximize crop competition, utilize mechanical weed control methods, prevent movement of weed seed, manage weed seed at harvest and prevent influx of weed into field by managing field borders (Norsworthy et. al 2012) . To address the growing resistance and preserve effective herbicide control, the EPA Pesticide Registration division has provided updated guidance for resistance management statements on labels in addition to guidance on education, training, and stewardships of herbicide in PRN 2017-1 Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling, and PRM2017-2 , Guidance for Herbicide Resistance Management Labeling, Education, Training, and Stewardship. The elements of these new requirements align with the best management practices for herbicide resistance outlined by Weed Science Society of America (WSSA). In a grower education initiative, Take Action has created a grower friendly version of the BMPs in the form of a one-page fact sheet (shown below).

Figure 1. Take Action Fact Sheet on Best Management Practices for Herbicide Resistance. (https://iwilltakeaction.com/resources/best-management-practices-for-herbicide-resistance)



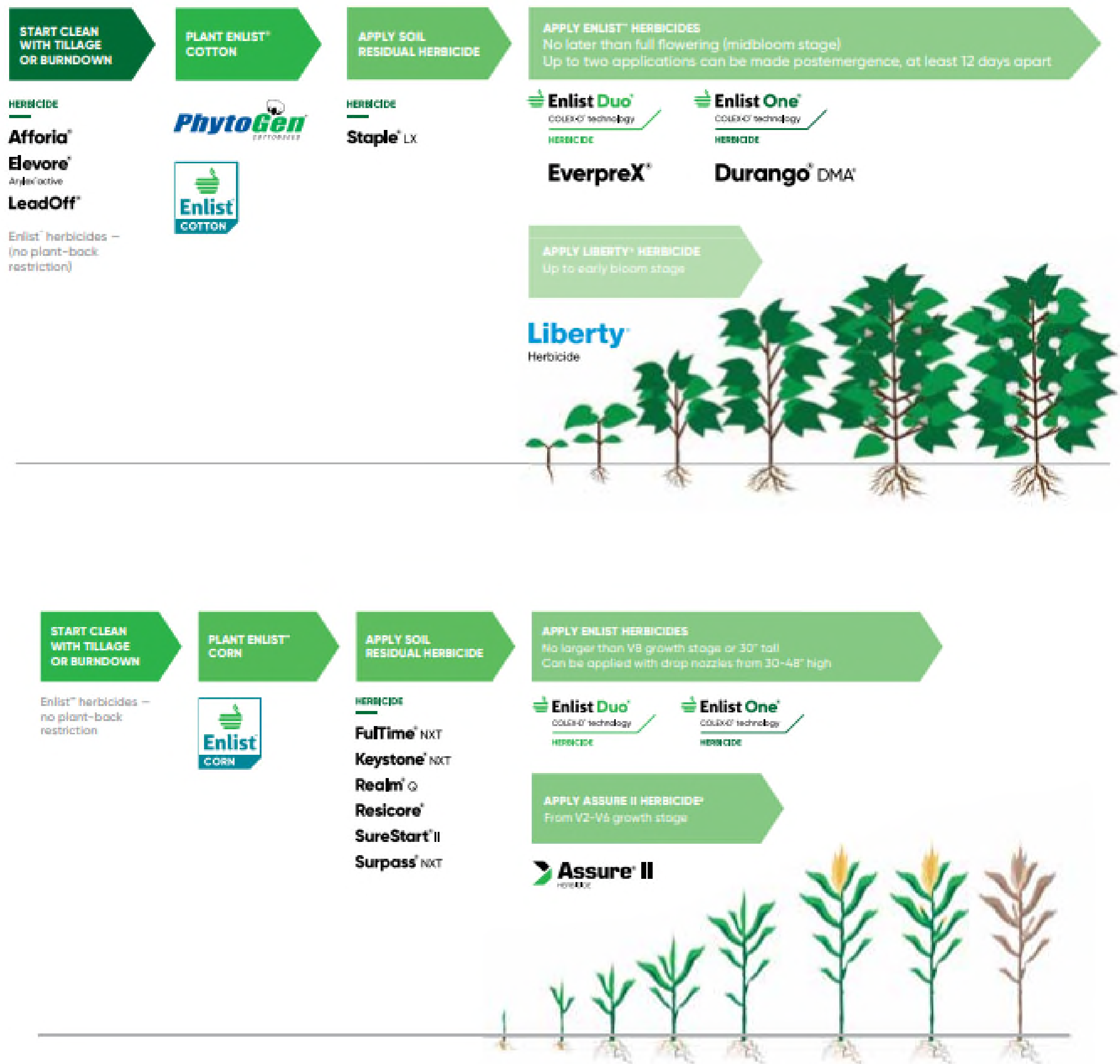
Enlist™ Weed Control System

Enlist™ weed control system promotes a program approach utilizing the best management practices defined by academia and industry for managing herbicide resistance (Corteva 2021). The Enlist weed control system recommends starting with a clean seed bed through tillage or burndown herbicide applications, use of residual herbicides at planting, timely post-emergence application of 2,4-D choline plus glyphosate or glufosinate to small weeds, inclusion of additional residual herbicide at the post-emergence timing, scouting following application and second post-emergence applications if needed to achieve control of new germinated weeds. A key advantage of the Enlist weed control system is that Enlist crops provide tolerance to 2,4-D choline, glyphosate and (for Enlist E3® soybeans and cotton) glufosinate which allows three different herbicide modes of action to be utilized in the postemergence application. Enlist One® (with 2,4-D choline) should always be applied with either glyphosate or glufosinate so two modes of action are being applied to minimize the potential for selection of resistance.

Enlist Duo® and Enlist One herbicides are the only 2,4-D containing products authorized for use with Enlist crops. Enlist Duo® with Colex-D® technology is a premix of 2,4-D choline + glyphosate. Enlist One® with Colex-D technology is a single entity product containing 2,4-D choline which is used in tank mix with qualified glyphosate and (for Enlist E3 soybeans and cotton) glufosinate herbicides listed on EnlistTankMix.com. Multiple brands of glufosinate herbicides, including Liberty herbicide, are qualified tank mix partners for Enlist One.

Figure 2. Recommended Enlist weed control system for Enlist E3 soybean from the Enlist Weed Control System Product Use Guide. (Corteva 2021)

Figure 3. Recommended Enlist™ weed control system for Enlist® cotton and corn from the Enlist Weed Control System Product Use Guide. (Corteva 2021)



Protecting Herbicide Technologies

History has shown that relying on a single mode of action for weed control creates intense selection pressure for resistance. Delays in the commercial launches of Enlist and Xtend crops allowed the selection and spread of glyphosate resistant weeds which began over 15 years ago to continue. In cotton and soybean, glufosinate use has increased over 10 years for controlling glyphosate resistant Palmer Amaranth. During that time, the recommended rate of glufosinate has steadily been increased from 22 to 29 and now 32 fluid ounces per acre. The University of Arkansas has publicly stated that glufosinate resistant Palmer amaranth has been found (Unglesbee 2021). With cotton growers heavily relying on glufosinate to control Palmer amaranth since 2007, are we now on the cusp of widespread glufosinate resistance? Growers need access to more technologies and weed control options to manage resistance.

Protecting herbicides from future resistance should be important for the farmer, agricultural industry and EPA. To achieve long term utility, growers must implement a diversified weed management program. Resistance develops where selection pressure is high because of repeated use of a single mode of action herbicide. Restricting access to an herbicide due to a resistance concern could increase the selection for resistance to other herbicides. For example, preventing the use of glufosinate on an Enlist™ crop would limit postemergence applications to 2,4-D + glyphosate. If glyphosate resistant waterhemp or Palmer amaranth is present, then the selection pressure increases for 2,4-D resistance. Likewise, restricting use of 2,4-D in Enlist cotton or Enlist E3® soybean will increase selection pressure for glufosinate resistance. Products containing PPO herbicides are widely utilized for pre-emergence control of waterhemp and Palmer Amaranth, emergence of glufosinate resistance will increase selection for PPO resistance. Maximizing the number of effective modes of action available to utilize in a diversified weed management system, that include crop rotations, herbicide programs, cultural practices and sanitation, is key to managing resistance.

Looking into the future, new technologies are currently under development that will likely reduce the selection and propagation of resistance in the years ahead. The discovery pipelines of agricultural chemical companies are indicating new modes of action are currently in early-stage research with commercial launches being years away. In the short-term, the new herbicide tolerant crops, such as Enlist, XtendFlex and GT27 crops, enable the use of multiple modes of action in a weed control program to combat resistance. Herbicide tolerant crops are under development containing multiple herbicide traits as companies continue to license herbicide traits from other companies to create crops with up to 5 different herbicide traits to ensure growers have options for weed control and managing resistant weeds in the future. Equipment manufacturers are developing seed destruction equipment to devitalize weed seed at harvest to reduce the number of weed seeds being deposited in the soil seed bank. Targeted application equipment and machine learning are under development which may provide new alternatives on how to control weeds. These new technologies will aid in diversifying the weed management systems and reduce selection pressure leading to herbicide resistance.

In the short-term though, the focus of regulatory agencies, academia and industry should be on implementing multi-facet weed management systems that reduce the selection pressure for herbicide resistance thus extending the utility of current technologies into the future.

The steps that Corteva is taking to provide a high level of protection and proactive management around stewardship of The Enlist weed control system for weed resistance management include the following:

- Training of applicators, growers and other industry influencers on the Enlist weed control system
- Promoting best management practices for herbicide resistance management
- Promotion of the use of multiple modes of action for both residual and postemergence control
- Monitoring and investigation of potential resistance report to respond rapidly to early signs for resistance.
- Annual grower surveys assessing growers' adherence to use agreements requiring growers only use approved herbicides and adopt herbicide resistance BMPs. Survey also assesses how growers received Enlist weed control system training that includes resistance management.

Conclusions

The Enlist™ system has emerged as a highly promising technology for an integrated approach to weed management that will protect US corn, soybean, and cotton agriculture from the problems that have arisen after many years of overreliance on a single herbicidal mode of action. During the past 4 years of introduction of the Enlist system, Enlist herbicides have been applied to more than 26 million acres of Enlist crops and strong future growth is projected as growers seek out this best-in-class technology. The program approach associated with the Enlist System is designed to minimize the likelihood for development of weed resistance, and Corteva has diligent monitoring systems in place for early detection and intervention. In the past 4 years of Enlist herbicides being used in the US, no weed control failures because of weed resistance have been confirmed. While 2,4-D use over the past 75 years has resulted in limited resistance, 2,4-D resistance has occurred in nature and stewardship efforts are underway to monitor for the early detection of 2,4-D resistance. Corteva is committed to the stewardship of the Enlist weed control system and developing a holistic approach to weed management.

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